MULTIMEDIA UNIVERSITY ™

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2022/2023

EEL2216 – CONTROL THEORY

(LE / EE / CE / NE / TE)

2 OCTOBER 2023
9:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **SIX** pages including cover page with **FOUR** questions only.

2. Answer **ALL** questions and print all your answers in the answer booklet provided.

3. All questions carry equal marks and the distribution of the marks for each question is given.

Question 1

(a) Consider the differential equation

$$\frac{d^2y(t)}{dt^2} + 7\frac{dy(t)}{dt} + 10y(t) = 3x(t)$$

Given that $x(t)$ is a unit step function, solve for $y(t)$ assuming zero initial conditions. [10 marks]

(b) It is given that:

$$F(s) = \frac{5s + 7}{s(s^2 + 2s + 8)}$$

Find the final value of $f(t)$ using the final value theorem. [2 marks]

(c) Determine the transfer function, $C(s)/R(s)$ for the Signal Flow Graph (SFG) shown in **Figure Q1(c)** by using Mason's gain formula. [13 marks]

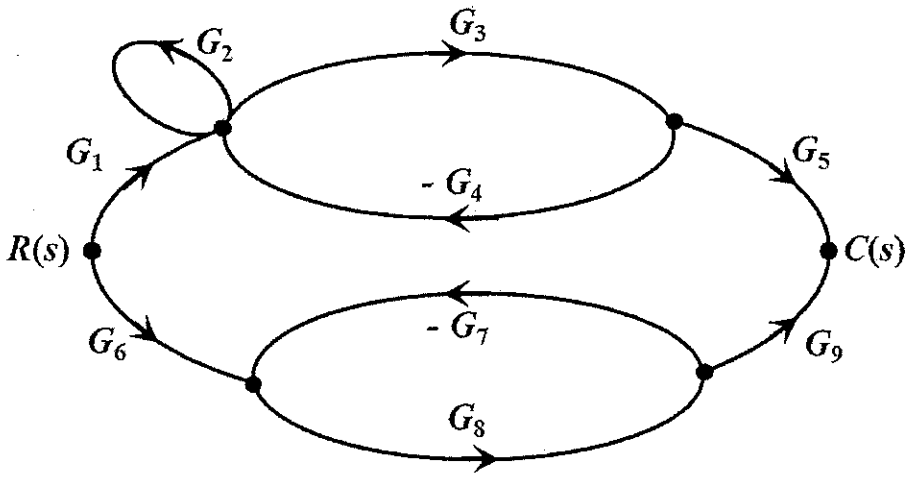

Figure Q1(c)

Continued...

Question 2

(a) Consider a negative unity feedback system shown in **Figure Q2(a)**.

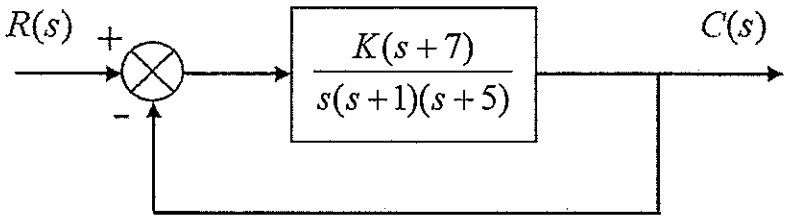

Figure Q2(a)

(i) Determine the range of stability for K using the Routh-Hurwitz criterion. [6 marks]

(ii) Calculate the steady state errors of the system with a step input and a parabolic input, respectively. [3 + 3 marks]

(b) For the loop transfer function given as follows:

$$G(s)H(s) = \frac{K}{(s+2)(s+4)(s+6)}$$

(i) Determine the starting and ending points of the root locus. [2 marks]

(ii) Find the intersection (centroid) and angles of the asymptotes. [3 marks]

(iii) Determine the range of K for stability and the intersection with the imaginary axis in the s-plane. [5 marks]

(iv) Sketch the root locus given that the breakaway point is at s = -2.85. [3 marks]

Continued...

Question 3

The forward path transfer function of a negative unity feedback system is given by:

$$G(s) = \frac{K}{s(s+1)(s+4)}$$

(i) Determine the magnitude and phase of $G(j\omega)$ at $\omega = 0$ and $\omega = \infty$. [9 marks]

(ii) Calculate the intersection point of the Nyquist plot with the negative real axis. [8 marks]

(iii) Sketch the Nyquist plot using the values obtained in parts (i) and (ii). [4 marks]

(iv) Suggest a value for K that will make the system unstable. Justify your answer. [4 marks]

Question 4

A negative unity feedback system has a forward path transfer function as follows:

$$G(s) = \frac{2}{s(s+0.3)}$$

(i) Find the damping ratio, ζ and the undamped natural frequency, ω_n in closed loop without any controller. [9 marks]

(ii) Design a proportional-derivative (PD) controller $G_c(s) = K_D s + K_P$ in order to change the damping ratio, ζ to a new value of 0.9. Let $K_P = 1$. [12 marks]

(iii) Compute the ramp error constant for the closed loop system with the PD controller. [4 marks]

Continued...

Appendix - Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $1(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!} \quad (n=1, 2, 3, \ldots)$	$\frac{1}{s^n}$
$t^n \ (n=1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at} \quad (n=1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at} \ (n=1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$

Continued...

Appendix - Laplace Transform Pairs (continued)

$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at-1+e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}t$	$\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$
$-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}t-\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2+2\zeta\omega_n s+\omega_n^2}$
$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}t+\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$
$1-\cos\omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t-\sin\omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin\omega t-\omega t\cos\omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega}t\sin\omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
$\frac{1}{\omega_2^2-\omega_1^2}(\cos\omega_1 t-\cos\omega_2 t)\ \ (\omega_1^2\neq\omega_2^2)$	$\frac{s}{(s^2+\omega_1^2)(s^2+\omega_2^2)}$
$\frac{1}{2\omega}(\sin\omega t+\omega t\cos\omega t)$	$\frac{s^2}{(s^2+\omega^2)^2}$

End of Paper